Bellota Fish Ladder Evaluation

Fishery Foundation of California ***January, 2005***

Background

In order to assist with fish movement along the Calaveras River two fish ladders have been placed at the Bellota Dam. A view of the two ladders is shown below.

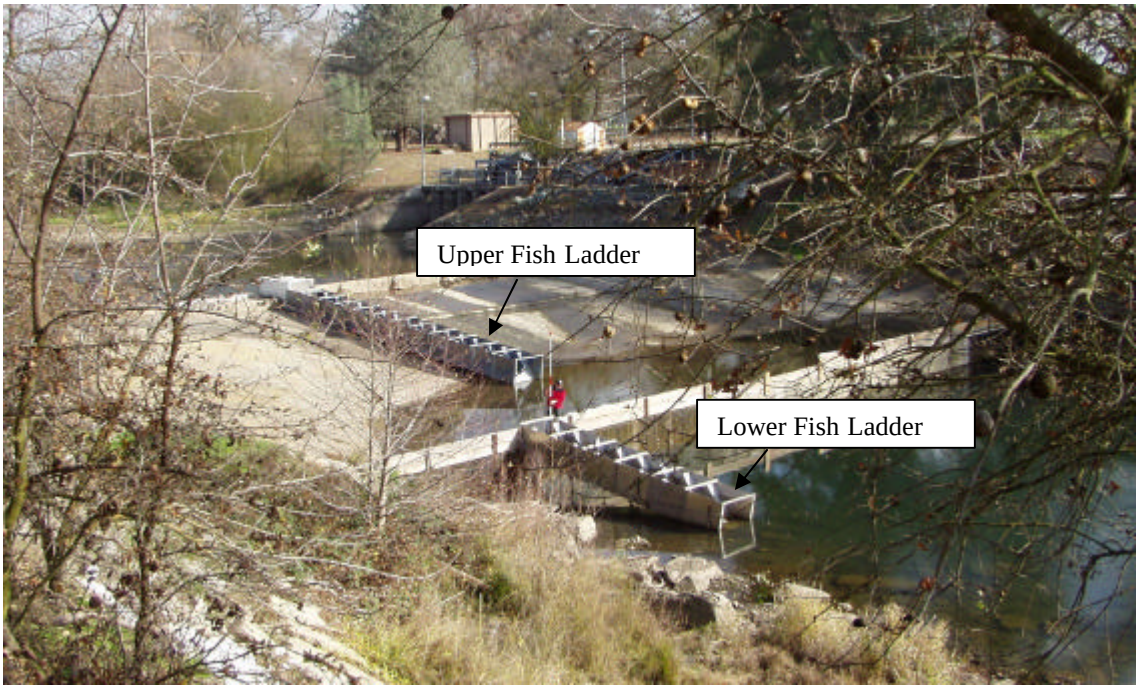

Figure 1. Bellota Project Site Photo

The upper fish ladder has been in operation for several years. The lower fish ladder was replaced in September 2003. Both ladders are the basic Denil fish ladder design. The current operation of the dam directs lower flow through the fish ladders with the use of flashboards in the dam. The flashboards at the downstream section of the dam have a lower section in the middle to pass higher flows. There is a concern that this method allows too much concentrated water down the middle of the dam attracting fish away from the fish ladder. The Fishery Foundation would like to evaluate the current operation of the dam in relation to the fish ladders' performance and capacity and make recommendations for potential improvements in operations.

Evaluation Criteria

Many factors will affect the performance of the fish ladders. These include the amount of flow allowed down the ladder and the tailwater conditions on the ladder. Both of these factors were evaluated for the two ladders using a HEC-RAS model and developing rating curves for the dam operation and ladder capacities.

A survey of the project area was performed in order to develop the HEC-RAS model. The model was mainly used to determine the tailwater conditions at various flows. The tailwater and corresponding ladder submergence has a great effect on how well the fish ladder will attract and pass fish. The minimum desirable tailwater elevation is approximately one foot above the last v-notch in the ladder.

Lower Fish Ladder Results

The surveyed elevations of the project area are relative to a fixed point on the upper dam. The relative elevation of the final v-notch on the lower fish ladder is 88.55 ft. Cross sections along the downstream river were put into a HEC-RAS model for analysis. These sections were used to determine the water surface elevation directly downstream of the fish ladder. The fish ladders were not modeled using HEC-RAS as the model is not set up to run hydraulics of the ladders. The fish ladder capacity at various headwater surface elevations was estimated using empirical equations developed for the Denil type fish ladder.

In addition to modeling the river tailwater and developing ladder flow capacity, a rating curve for the dam section was developed for the existing conditions (section in middle of dam with lower flashboards, see figure below) and for the condition when all of the flashboards are in.

Figure 2. View of current operation of lower dam

Headwater Analysis

The analysis shows that for the ladder design flow rate of 15cfs the headwater on the fish ladder must be at a depth of 2 feet. However, at a depth of 2 feet the flow over the weir in the lower middle section of flashboards is over 66cfs. This means that the majority of the flow is crossing over the lower flashboard section. In order to optimize the fish ladder usage it is recommended that the flashboards in the middle section be inserted to make the section level or if a center spill is desired that the notch depth be significantly smaller. This will raise the water surface elevation for the lower flows and force the majority of the flow through the fish ladder creating more fish attraction flows at the ladder.

Figure 3 shows the rating curves for the lower fish ladder relative to flow over the dam with and without the center flashboards inserted.

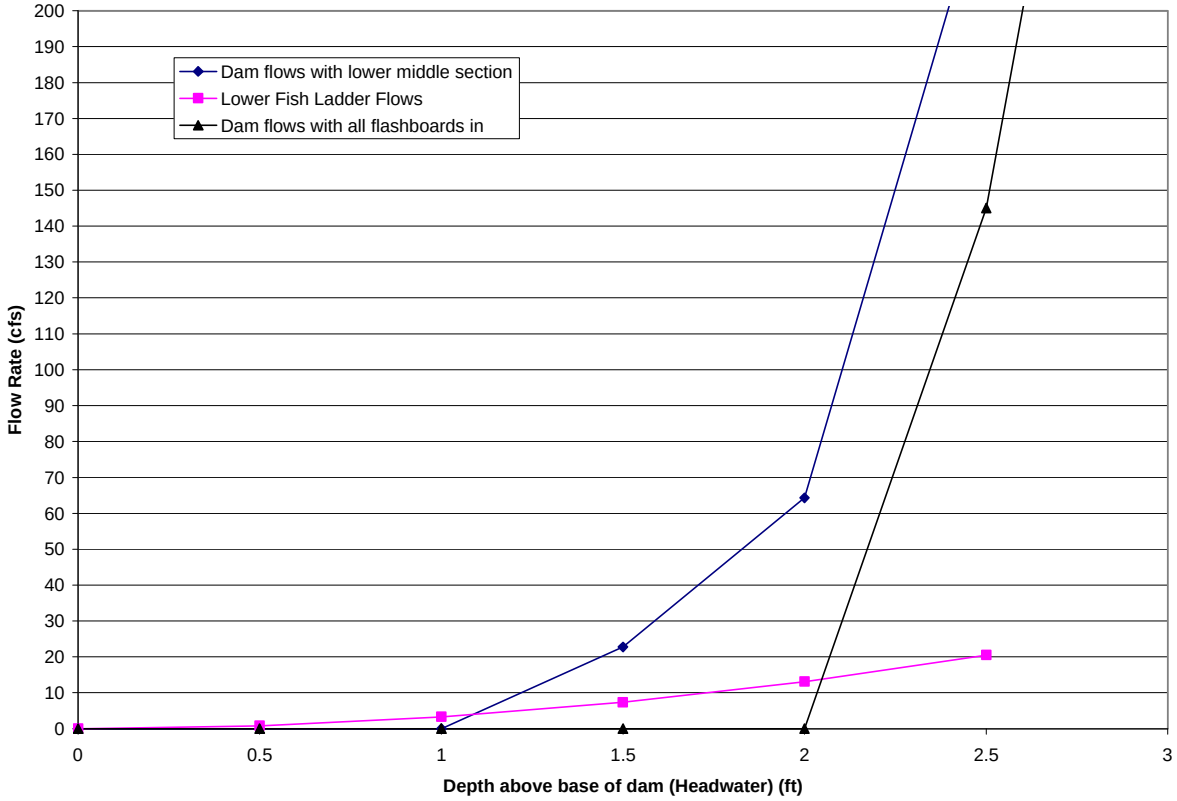

Figure 3. Graph of headwater depth versus flow for lower dam.

Tailwater Analysis

In addition to having the necessary headwater, the water surface downstream of the ladder (tailwater) is also important in determining its effectiveness. The resulting water surface elevations just downstream of the fish ladder for various flows of interest are shown in the table below. When the entire river flow is directed to the ladder at 15cfs, the tailwater is the same elevation as the final v-notch. This creates an initial jump for the fish of approximately 1.5 feet to enter the ladder. Raising the tailwater (at least one foot at lower flows) will greatly improve the ladder operation.

Flow Rate (cfs)	Water Surface Elevation d/s of Ladder (ft)
15	88.58
100	89.27
200	89.76
500	90.79
1,000	91.94

The tailwater is most effective when it is approximately one foot above the invert of the final v-notch on the ladder. The relative elevation of the final v-notch on the lower fish ladder is 88.55 ft. The most effective tailwater occurs when the flow rate is close to 200cfs.

Upper Fish Ladder Flows

Headwater Analysis

The current operation of the upper dam allows the majority of the flow to enter the fish ladder. However, the fish ladder cannot be utilized to its full capacity until the water is approximately one foot above the flashboards (see figure below). It is our recommendation that in order to utilize the full capacity of the fish ladder the flashboards should be raised to the height of the fish ladder. The maximum capacity of the upper fish ladder is approximately 24cfs. The upper fish ladder has a greater capacity as it is at a steeper slope and the walls are deeper allowing a higher water surface in the ladder when compared to the lower fish ladder.

Figure 4. View of current operation of the upper dam.

Tailwater Analysis

The tailwater on the upper ladder is directly related to the operation of the lower dam. When the flashboards are lower in the middle of the lower dam (as in the current operation), more flow is allowed downstream and the water surface at the downstream end of the upper fish ladder is lower. However, even with this current operation there is sufficient tailwater once the river flow reaches approximately 30cfs. If all of the lower dam flashboards are in and level, there is sufficient tailwater with a flow of approximately 15cfs.

Conclusions

Based on the hydraulic analyses for the Bellota fish ladders presented in this report we have made the following conclusions:

Lower Ladder

1. With the flashboards in their current arrangement (lower mid section) the ladder effectiveness drops off proportionally as the river flow increases above a river flow of approximately 40cfs. At this flow 30cfs crosses over the dam and only 10cfs passes through the ladder.

2. With the center flashboards level to the rest, all flow passes through the ladder up to 20cfs. Above this rate, the flow will spread evenly over the entire dam, not concentrating flow over the dam until the flows are quite high.

3. The tailwater at the lower ladder is less than optimum during low flow conditions (up to 200cfs).

Upper Ladder

1. The upper ladder flashboards can be raised to increase the flow through the ladder.

2. The current tailwater condition is adequate.

Recommendations

Recommendations to improve ladder operations include:

1. Inserting the center flashboards on the lower dam section level with the others or at least put in an 8-inch minimum boards to increase the headwater at the lower ladder.

2. Increase the tailwater at the lower ladder by constructing a boulder weir across the bottom end of the tailwater pool.

3. Install the upstream flashboards at closer to the top elevation of the upper fish ladder to increase flow to the ladder.

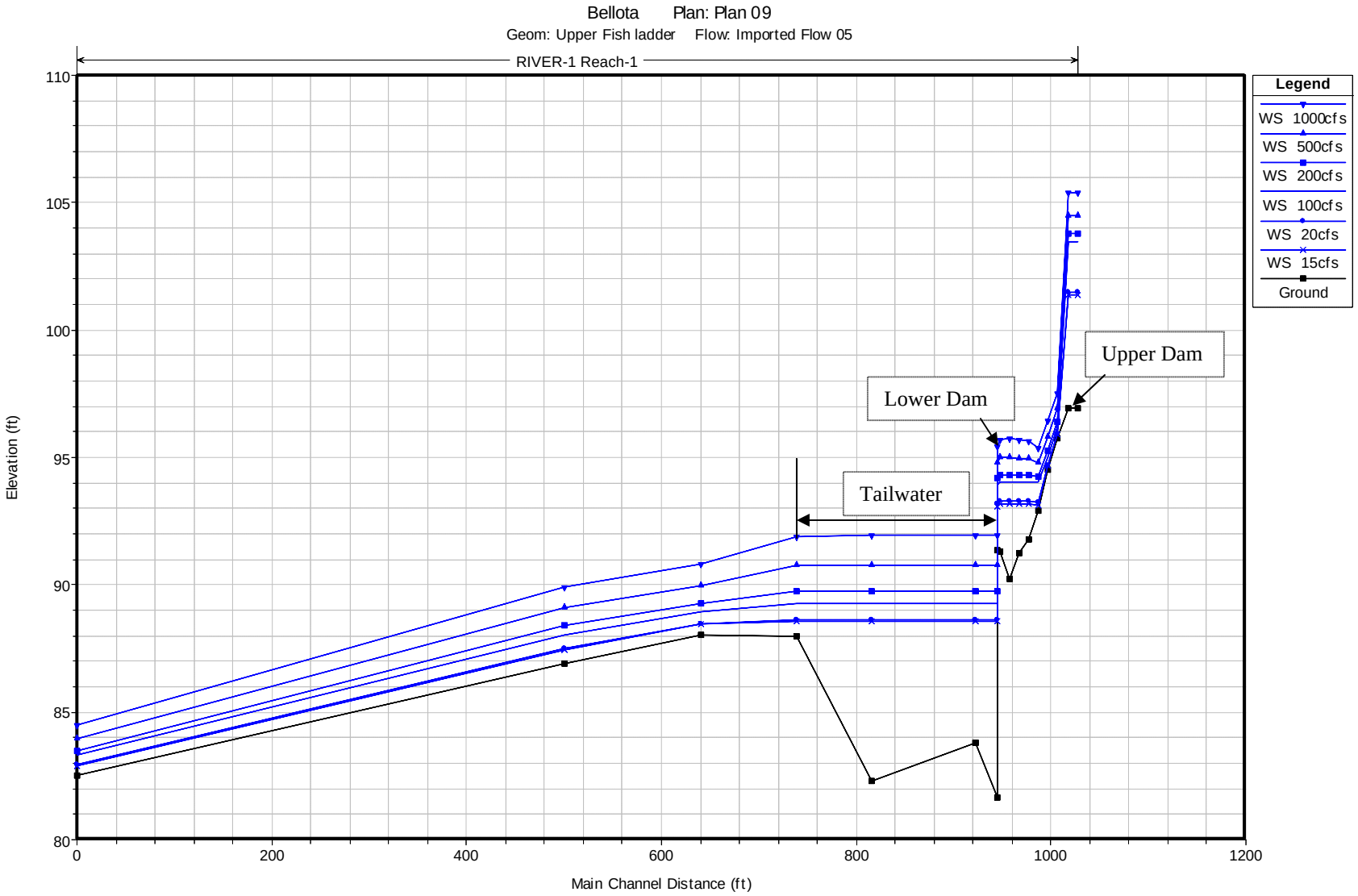

Figure 5. Profile output from HEC-RAS Model